Analytical Evaluation of the Effectiveness of Minimum Separation Distance and Turn-Signal Onset Rules for Lane Change Crash Avoidance System Warning Onset

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ABSTRACT

This paper reports on the potential effectiveness of two rules to trigger a driver warning for lane change crash avoidance systems (CAS) given the presence of a vehicle in the blind spot. A minimum-separation rule triggers a driver warning whenever the Subject Vehicle (SV) and Principal Other Vehicle (POV) are closer than some minimum lateral separation distance. A turn-signal onset rule triggers a driver warning when the driver activates the turn signal indicator 4
and there is a vehicle in blind spot. The LCAVOID program, suitably modified, was used to assess the crash avoidance potential of each warning rule using on-the-road lane change data from a small-scale instrumented vehicle study. In each iteration, a conflict situation was simulated to determine the maximum time available for driver surprise reaction time to the warning. For the range of conditions modeled, the results indicate that the minimum separation rule is unlikely to provide substantial crash avoidance without a concomitant increase in nuisance alarms. The turn signal activation rule, however, appears to hold great promise in supporting CAS implementation for those drivers who use their turn signals. Details of the analysis and recommendations for Lane Change CAS research and development are provided.

A Taxonomic Analysis of Crash Contributing Factors and Prospects for ITS Crash Countermeasures

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ABSTRACT

A multi-year study was recently completed that examined several major highway crash types. The examined crash types included rear-end, roadway departure, backing, lane change, opposite-direction, and various intersection-related crashes, Each analysis addressed the crash problem's size, crash sub-types, contributing or causal factors associated with each crash, potential ITS crash countermeasures concepts, and crash avoidance requirements. A series of reports based on this work has been prepared.

This paper summarizes the key characteristics and contributing or causal factors associated with each crash type. These contributing factors are organized into a taxonomy to illustrate common properties among them. This taxonomy is used to indicate generic crash contributing factors and circumstances that may not be amenable to crash avoidance system alleviation or that may affect the benefits to be derived from development and implementation of ITS crash countermeasures.

INTRODUCTION

Crash Avoidance Systems (CAS) development requires an understanding of the size of various crash problems and their etiology. It is equally important to understand the time and distance budgets required and available for crash avoidance in order to assess the role the driver might play. An IVHS program sponsored by the Volpe National Transportation Systems Center (VNTSC) and the National Highway Traffic Safety Administration Office of Crash Avoidance Research (NHTSA OCAR) pursues this important step. The present paper provides a brief synopsis of key findings from the crash problem studies and presents a taxonomy of contributing or causal factors that illustrates common properties among them.

SYNOPSIS OF CRASH ANALYSES AND CRASH AVOIDANCE SYSTEM CONCEPTS

Table 1 summaries the findings from the crash problem studies. Percentages are of U.S. police-reported crashes in 1993 (I), derived from the series of reports prepared as part of the IVHS program crash problem studies (2,3, 4, 5, 6, 7,8,9, 10; See also 11, 12, 13, 14) The data in this table were determined by searches of the Genera1 Estimates System (GES) crash database together with a clinical analysis of samples of crash cases carried out by expert crash investigators at Calspan Corporation. The materials to support such analyses were detailed crash reports from the National Accident Sampling System Crashworthiness Data System VASS CDS]. These reports included driver and witness statements, police comments, coded variables on reporting sheets, scaled schematics, measurements taken at the crash scene, and photos of the involved vehicles. The sample sizes of detailed crash cases examined in the various crash problem studies were limited and therefore not fully representative. However, the figures in Table 1 provide some indication of the relative incidence of different crash types. As a point of reference, approximately 6,100,OOO police-reported crashes occurred in 1993 according to the General Estimates System (GES) statistics. The eight crash types analyzed account for roughly 72% of all police reported crashes. Crashes not analyzed include crash types such as animal strikes, untripped roil-avers, and at-grade railroad crossing crashes.

SIMULATOR EVALUATION OF HEAVY-VEHICLE DRIVER WORKLOAD: II: COMPLEX SECONDARY TASKS

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Previous research has shown that heavy-vehicle driver workload can be measured in a simulator with simple secondary tasks such as choice reaction time and immediate recall (Kantowitz, 1995). The present experiment replicates and extends these findings to complex tasks requiring drivers to use cellular phones and to interpret text message displays. Fourteen commercial drivers each drove eight simulator modules, each 100,000 feet in length. In-cab tasks were divided into cellular phone dialing, phone dialogue, text message reading, tachometer reading, clock reading, and manual radio tuning. These were evaluated in light and heavy traffic with and without pedestrian detection tasks. Complex tasks requiring message reading had the greatest impact upon driver performance. Results illustrate both advantages and limitations of driving simulators.

INTRODUCTION

Previous research using elementary secondary tasks has demonstrated that driver workload can be measured in a heavy-vehicle driving simulator (Kantowitz. 1995). Two key assumptions in interpreting dual-task data as measures of workload are: (1) performing the secondary task does not alter primary-task performance, and (2) the driver is devoting sufficient attention to the driving task. These assumptions held in previous research (Kantowitz, 1995) and two secondary tasks, reaction time to reading the vehicle tachometer and immediate recall of a 7-digit number, provided effective measures of driver workload. However, these elementary (secondary) tasks are seldom performed by commercial drivers on the road. Hence, the present experiments extend earlier findings by using secondary tasks that are more realistic and represent tasks that do occur in commercial vehicles. Furthermore, we attempted where possible to match simulator secondary tasks to cellular phone tasks used in an on-the-road study of heavy-vehicle driver workload (Tijerina, Kiger, Rockwell, Tornow, 1995).

METHOD

Subjects

Fourteen drivers with tractor-trailer rig experience, holding Commercial Drivers Licenses, participated in the experiment. The mean age of the drivers was 47.1 years and they had a mean of 22 years commercial driving experience.

Apparatus

The STISIM low-fidelity simulator version 7.03 was used with parameters previously used for heavy-vehicle dynamics. The realistic test buck contained a functional truck steering wheel, brake and accelerator pedals. The roadway display was presented on a 20-inch CRT mounted on the hood of the cab, directly in front of the driver.

A Motorola Attache model TX100 cellular phone, identical to that used **in the** field study, was placed in the cab. Text messages were presented on a 7-inch VGA green phosphor CRT mounted atop the center of the **dash** with display characters that subtended 16 to 18 minutes of arc at a viewing distance of between 32 and 36 inches. An auditory alarm (0.5 sec, 900.9 Hz) announced that a message had appeared on the display.

Scenarios

Table 1 shows the eight 100,000-foot driving scenario modules.

Driving time was about 30 minutes per module. Heavy traffic consisted of 125 vehicles in the approaching lane versus 55 vehicles for Light traffic. The lane was 12 feet wide. Only the Easy curves (radius of curvature from l/600 to l/1000) of previous research (Kantowitz, 1995) were tested. Table 2 shows the presentation sequence.

Modules S3' and S4 included six pedestrians: four that crossed the road at a speed of 5 feet per sec and two that were stationary. Pedestrians began moving 5 sec before the vehicle would reach their position at constant velocity Drivers were instructed to beep the vehicle horn when a pedestrian was detected in the roadway.

USE OF WORKLOAD ASSESSMENT MEASURES AND METHODS TO ASSESS SAFETY-RELEVANT IMPACTS OF IN-VEHICLE DEVICE USE AMONG HEAVY VEHICLE DRIVERS

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ABSTRACT

As a result of Intelligent Transportation System (ITS) initiatives in the United States and abroad, a wide variety of in-vehicle information systems are being proposed and developed for use in heavy trucks and cars. Such systems can improve transport efficiency, driver satisfaction, and highway safety. However, these technologies must be designed such that their use does not distract the driver or otherwise interfere with the driving task. This interference is what is referred to by the term "driver workload" in this paper. What is needed is a workload assessment protocol that can be used to evaluate the safety impacts of in-vehicle systems and promote a driver-centered design.

In response to this need, a program of research was undertaken to develop a safety-relevant workload assessment protocol. This paper presents: a brief description of the resulting protocol document; approaches taken to establish the safety relevance of the measurement system; application of the protocol to cellular phone use and text message displays in heavy vehicles; and future directions.

INTRODUCTION

Intelligent Transportation System (ITS) initiatives have led to various types of driver information systems that are being proposed and developed for use in heavy trucks and cars. These systems include land navigation and route guidance systems; text displays (e.g., pick-up address, package type); vehicle subsystem monitoring and status systems (e.g., tire pressure, oil pressure, brake failure, load shifting); computerized trip recorders (e.g., automatic record of speed RPM, stops; driver entry of fuel purchase; state-line crossings); sophisticated communication links (e.g., cellular phone systems); and collision avoidance systems (e.g.. radar, Ma-red, and TV systems). If properly designed, such technologies have great potential to improve the efficiency of commercial and public transport, increase driver satisfaction, and enhance highway safety.

Studies suggest that driver inattention is a primary or contributing factor in as many ns 50% of all traffic accidents (Sussman, Bishop, Nadnick, and Walter, 1985). This suggests that there is good reason to be concerned about the potential for a new in-cab device to distract the driver Tom the primary driving task. This device-induced distraction or interference with safe driving is what is meant by the term "driver workload" in this paper. Without a driver-oriented assessment of device-induced workload, the safety impacts of a system remain largely unknown. Furthermore, a workload assessment can be useful in developing a driver-oriented product design.

What is needed is a system of safety-relevant measures and methods to assess the safety implications of a device from the driver's perspective, i.e., a workload assessment protocol. In response to this need, the National Highway Traffic Safety Administration (NHTSA) initiated the program of research entitled, "Heavy Vehicle Driver Workload Assessment." The goal of this program was the development of a heavy vehicle driver workload assessment protocol that can serve as a basis for standard practice in the field of driver human factors test and evaluation. That protocol is described in Tijerina, Kiger, Rockwell, and Wierwille (1995). Additional reports from the program of research are referenced and summarized in Tijerina (1995).

This paper presents a brief description of the protocol document, approaches taken to establish the safety relevance of the measurement system, application of the protocol to cellular phone use and text message displays in heavy vehicles, and future directions. Additional discussion of this project may be found in Tijerina, Kantowitz, Kiger, and Rockwell (1994).

THE WORKLOAD ASSESSMENT PROTOCOL AND MEASUREMENT SYSTEM

The Tijerina, Kiger, Rockwell, and Wierwille (1995) report (henceforth referred to as the protocol document) begins with an introduction that provides background material on the rationale for candidate workload measure selection and omission. It also discusses various means of assessing the validity and safety relevance of workload measures. The protocol itself is organized in terms of the steps depicted in

DRIVING SIMULATOR TESTS OF LANE DEPARTURE COLLISION AVOIDANCE SYSTEMS

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ABSTRACT

This report presents the results of a simulator-based exploratory study of Collision Avoidance System (CAS) concepts suitable for roadway departure collision avoidance. Roadway departure crashes account for significant percentages of both the total number of crashes and the number of fatal crashes in the United States. CAS support that could avert or minimize the severity of even a fraction of these crashes would prove beneficial to the driving public.

The purpose of the study was to evaluate the following items from a driver-oriented perspective. Sixty-four Volunteers participated at the Iowa Driving Simulator (IDS), a six-degree-of-freedom, moving-base simulator with a wide field-of-view image generation system. Sixteen of the participants were randomly assigned to serve in a control group without CAS support: the remaining 48 participants were randomly assigned to groups of 16 in each of three CAS Interface groups: auditory, haptic, or combined-modality. Within the CAS groups, participants were further assigned to different levels of four factors: directionality of CAS display (directional or non-directional), Onset (early CAS onset or late CAS onset), and Algorithm (Time-to-Line-Crossing [TLC] versus Time-to-Trajectory Divergence [TTD]) for lanekeeping.

All participants were assigned to either high or low magnitude hazard conditions. The lateral disturbance collision hazard involved a simulated lateral offset (i.e. wind gust) applied while the driver was engaged in an in-vehicle distractor task; low hazard magnitude was equated to a small lateral offset and high hazard magnitude was equated to a large lateral offset. In addition. participant performance was assessed during normal (non-hazard) lanekeeping early and late in a 40-minute simulator session.

Results suggest that the concept of a roadway departure CAS has potential. Given that a CAS is to be developed, the data indicate that directional displays have some performance advantages and consumer preference. Based on the evidence gathered in this study, auditory and haptic interface types merit further investigation and development. However, a combined-modality display may

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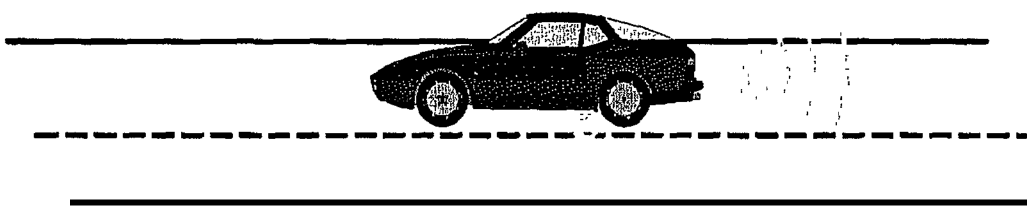
Development of Performance Specifications for Collision Avoidance Systems for Lane Change, Merging, and Backing

Task 3 - Human Factors Assessment of the Driver Interfaces of Existing Collision Avoidance Systems



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16. Abstract

This report describes the assessment of the driver interfaces of a type of electronics-based collision avoidance systems that has been recently developed to assist drivers of passenger vehicles in avoiding certain types of collisions. The electronics-based crash avoidance systems studied included: those which ***detect*** the presence of objects located on the ***left and/or right sides*** of the vehicle, called Side-Looking Collision Avoidance Systems, or SCAS; those which detect the presence of objects located to the rear of the vehicle, referred to as Rear-Looking Collision Avoidance Systems, or RCAS; and those which enhance ***the driver's ability*** to see the presence of objects located to the rear of the vehicle using video cameras (also called RCAS). As many side and rear collision avoidance systems as could be obtained, including several pre-production prototypes, were acquired and tested. The testing focused on measuring the performance of the systems' sensors and assessing the qualities of the systems' driver interfaces. The sensor performance data is presented in an accompanying report by TRW.

One goal of this research was to evaluate, based upon the principles of human factors, how well the driver interfaces of the collision avoidance systems studied were designed. The strengths and weaknesses of each driver interface were determined. Overall, while none of the SCAS had an "ideal" interface, most of the systems had ergonomically acceptable interfaces. Not surprisingly, the commercially available systems tended to have better driver interfaces than did the prototypes. Another goal of this research was to provide advice to future designers of collision avoidance warning system driver interfaces as to ergonomically desirable or undesirable features. From the interface evaluations performed, the authors have developed a preliminary set of driver interface performance specifications that may be of aid to future SCAS driver interface designers.

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Human Factors Evaluation of Existing Side Collision Avoidance System Driver Interfaces

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Human Factors Evaluation of Existing. Side Collision Avoidance System Driver Interfaces

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ABSTRACT

This paper describes the assessment of driver interfaces of a type of electronics-based collision avoidance systems that has been recently developed to assist drivers of vehicles in avoiding certain types of collisions. The electronics-based crash avoidance systems studied were those which detect the presence of objects located on the left and/or right sides of the vehicle, called Side Collision Avoidance Systems, or SCAS.

As many SCAS as could be obtained, including several pre-production prototypes, were acquired and tested. The testing focused on measuring sensor performance and assessing the qualities of the driver interfaces. This paper presents only the results of the driver interface assessments. The sensor performance data are presented in the NHTSA report "Development of Performance Specifications for Collision Avoidance Systems for Lane Changing, Merging, and Backing -- Task 3 - Test of Existing Hardware Systems" [1].

One goal of this research was to evaluate, based upon the principles of human factors, how well the driver interfaces of the SCAS studied were designed. The strengths and weaknesses of each driver interface were determined. Overall, white none of the SCAS had an "ideal" interface, most had ergonomically acceptable interfaces. Not surprisingly, the commercially available systems tended to have better driver interfaces than did the prototypes. Another goal of this research was to provide advice to future designers of collision avoidance system driver interfaces regarding ergonomically desirable or undesirable features. From the evaluations performed, a preliminary set of driver interface performance specifications that may be of aid to future SCAS driver interface designers has been developed.

INTRODUCTION

This paper describes the evaluation of driver interfaces of a type of electronics-based system that has been recently developed to assist drivers of both light (passenger cars, pickup trucks, vans, and sport utility vehicles) and heavy (straight trucks and tractor-semitrailers) vehicles in avoiding certain types of crashes. The driver interface is defined as the displays and controls through which the driver interacts with the CAS and receives collision avoidance warning information. The type of electronics-based Collision Avoidance Systems, or CAS, examined was that which detects the presence of objects located on the left and/or right sides of the vehicle (referred to as side-looking collision avoidance systems or SCAS). These side-looking systems are intended primarily as supplements to the existing side- and rear-view mirror systems. The SCAS assist the driver during lane changes and merges by detecting adjacent vehicles.

This research was performed as part of a larger research program. "Development of Performance Specifications for Systems Which Assist in Avoiding Collisions During Lane Changes, Merging, and Backing" sponsored by the National Highway Traffic Safety Administration (NHTSA). The research was performed by TRW's Space and Electronics Group with assistance, during the Phase 1 testing, from NHTSA's Vehicle Research and Test Center (VRTC) and various subcontractors.

A portion of Phase I (Laying the Foundation) of the research program "Development of Performance Specifications for Systems Which Assist in Avoiding Collisions During Lane Changes, Merging, and Backing" was devoted to examining existing collision avoidance systems. As many SCAS as could be obtained, including several pre-production prototypes, were acquired and tested by TRW and VRTC. The focus of testing was on measuring the performance of the SCAS sensors and assessing the qualities of their driver interfaces. This paper documents the results of the evaluation of driver interfaces. A companion report, "Development of Performance Specifications for Collision Avoidance Systems for Lane Changing, Merging, and Backing – Task 3 - Test of Existing Hardware Systems" [I]. documents the examination of the SCAS sensors and the results of the assessment of their performance.

This paper is a summary of the NHTSA technical report "A Human Factors Assessment of the Driver Interfaces of Existing Collision Avoidance Systems" [2]. Readers desiring additional details about this research should consult this reference.

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An Evaluation of Electronic Pedestrian Detection Systems for School Buses

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An Evaluation of Electronic Pedestrian Detection Systems for School Buses

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ABSTRACT

Most fatalities due to school bus accidents involve pedestrians being shuck by the bus. All too frequently the school bus strikes a disembarking passenger because the driver was unaware of their presence near the bus.

To try to prevent this type of accident, two Doppler microwave radar-based pedestrian detection systems have been developed and are commercially available. These systems supplement regular school bus mirrors. They operate only while the bus is stationary. Both systems detect moving pedestrians either directly in front of or to the right of the bus.

The National Highway Traffic Safety Administration has performed a three-part evaluation of these pedestrian detection systems. The first part measured the field of view of each system's sensors. The second part evaluated the effectiveness and appropriateness of each system's driver interface. The third part was a small-scale operational evaluation. The systems were installed on school buses to obtain driver and student reactions. Results from these evaluations are presented.

INTRODUCTION

One of the highest priorities of the United States is the education of our children. Incumbent with this objective is the responsibility for safe transportation of our children to and from school and school-related activities. Thanks to the financial suppert of state and local governments, the United States has excellent, safe buses and well-trained drivers to provide this transportation.

Unfortunately accidents stil1 occur, sometimes resulting in injuries or fatalities to school children. In a 1989 study [l]' the Transportation Research Board found that, on the average, 12.0 children (plus 5.4 adults) per year are killed and 480 are seriously injured while riding in school buses to and from school or school-sponsored activities. Additionally, an average of 37.4 children (plus 7.2 adults) per year are killed and 160 are seriously injured while boarding or exiting school buses.

Of the 44.6 people per year who are killed in school bus loading zone accidents, an average of 31.2 (25.8 children and 5.4 adults) are struck by the school bus while the remaining 13.4 (11.6 children and 1.8 adults) are struck by other vehicles. Of the 160 children per year who are seriously injured, an estimated 56 are struck by the school bus, while the remaining 104 are struck by other vehicles.

While it is generally agreed that school buses enjoy a good safety record, and while the number of fatalities in school bus-related accidents may seem small when compared with the approximately 40,000 lives Iost each year in all motor vehicle accidents, each of these tragedies raises the question of 'How could this accident have been prevented?"

This paper focuses on methods for preventing people in the loading zone from being struck by a school bus. While the other types of school bus-related injuries and fatalities (injuries and fatalities that occur either while the person is on the bus or when he or she is struck by a vehicle other than the bus) are important, they were not studied during the course of this research program.

Each school bus sold in the United States is currently required to possess tinder-mounted, convex cross-view mirrors. The

* Numbers in brackets represent references listed at the end of this paper.